Abstract

Title: "Methodology and Results of Upscreening Electronic Parts in Plastic Packages"

The applicability of critical issues related to the use of Commercial Off-The-Shelf (COTS) Plastic Encapsulated Microcircuits (PEMS) to NASA environment was evaluated for MARS01. Based on the the critical issues, a custom upscreening flow was developed to address the needs and requirements of the application. Based on the outcome of the upscreening, risk mitigation of PEMS was ascertained as well as the cost and value of the upscreening methodology used. The data and conclusions of the methodology will be presented.

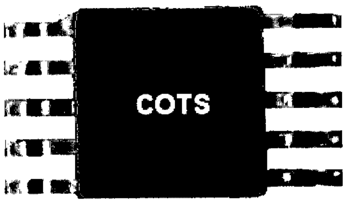
Authors: M.Sandor, S.Agarwal, E.Villegas

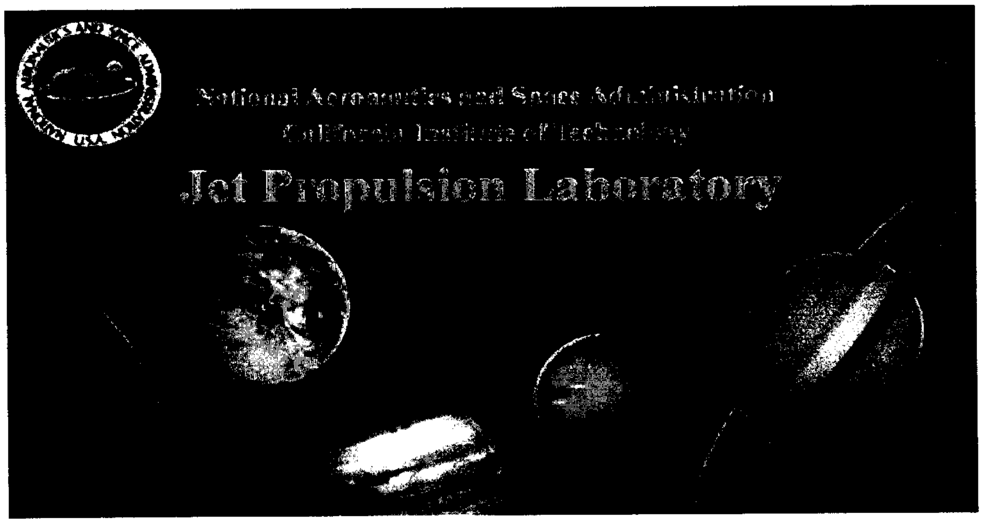
# Electronic Packaging for Space Applications Workshop

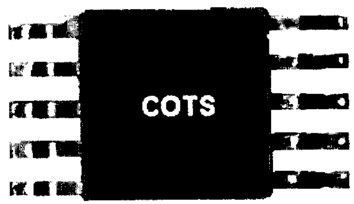
1999

## Commercial Off-The-Shelf (COTS) Program

## Methodology and Results of Upscreening Electronic Parts in Plastic Packages




Mike Sandor, Shri Agarwal, & Enrique Villegas
4800 Oak Grove Drive
Pasadena, CA 91109
Phone: (818) 354-0681 FAX: (818) 393-4559

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

# AGENDA:

ADVOCACY FOR COTS

MARS01 PROGRAM/REQUIREMENTS

MARS01 COTS SCREENING FLOW

TEST RESULTS - ELECTRICAL, C-SAM, BURN-IN

VALUE ADDED ANALYSIS (Risk Reduction)

VALUE ADDED ANALYSIS (Cost)

IMPACT of COTS$^{++}$ SCREENING

SUMMARY

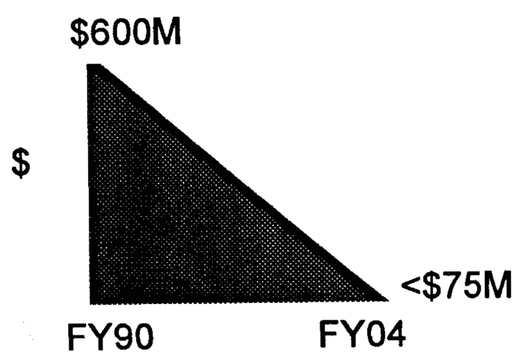
JET PROPULSION LABORATORY
Electronic Parts Engineering Office

# We Have Moved From Risk Avoidance to Risk Management:

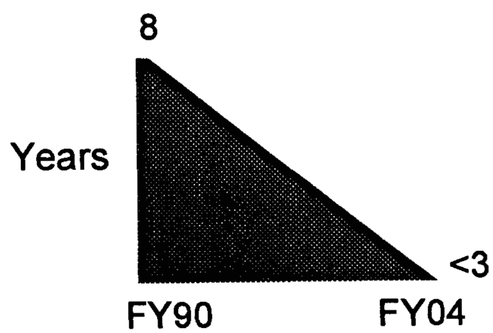
## JPL/NASA Project Drivers:

- Must infuse the latest technology (COTS is risky for High-Rel Space Application)
- Must significantly reduce development costs (COTS cost is conditional with risk)
- Must significantly reduce development time (COTS life cycle is short)

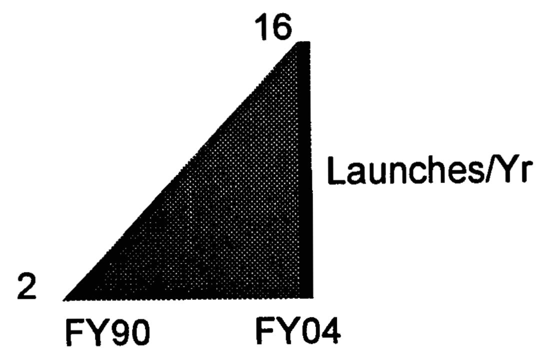
### Average Development Costs




### Average Development Time

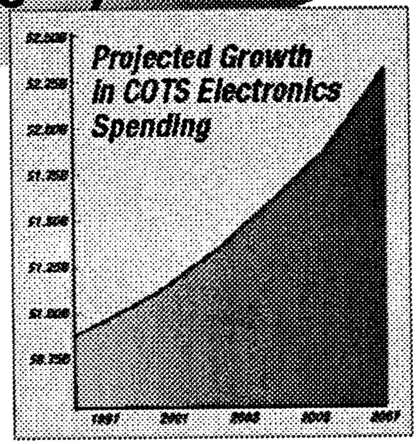



### Average Flight Rate



JET PROPULSION LABORATORY
Electronic Parts Engineering Office

# Advocacy for Using COTS(plastic packages):




Military & Aerospace Publication

1. State of-the-art parts are mostly available as COTS

2. COTS plastic parts performance capabilities continue to increase (e.g. processing power & high density memories)

3. COTS plastic parts enable reduction of hardware weight and volume

4. COTS plastic parts initial acquisition cost is less than ceramic

5.COTS plastic parts have been reported to demonstrate good to excellent reliability in commercial and aerospace applications

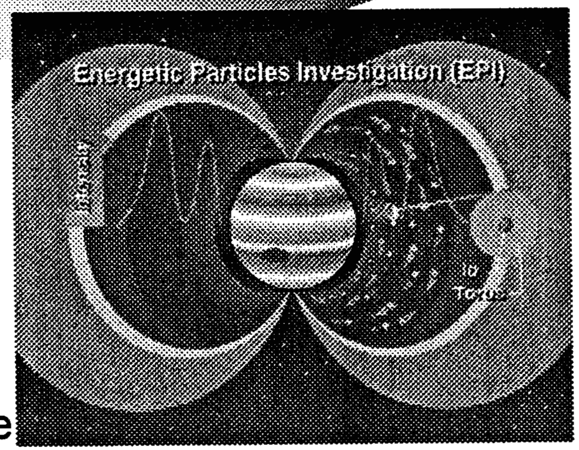
6. Often they are the only option when Grade 1 is not offered or available

# COTS PEM Risk Mitigation Addresses the Following Concerns:

- Narrow Temperature Range for Commercial Grade
- Plastic Assembly Quality
- Lot Non-Uniformity & Traceability
- Adequacy of Vendors Testing
- Infant Mortality
- Die Construction and Quality

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

## Radiation Requirements Complicates COTS for Space Applications:




**Rad Hard Assurance often unknown**

**Radiation requirement is unique-**

Can't leverage off other high rel users like automotive

**TID response depends on process-**

"Positive" process changes can reduce radiation tolerance

**SEE depends on circuit design and dimensions-**

Commercial vendor can change these without notice

**No good way of predicting radiation response without testing-**

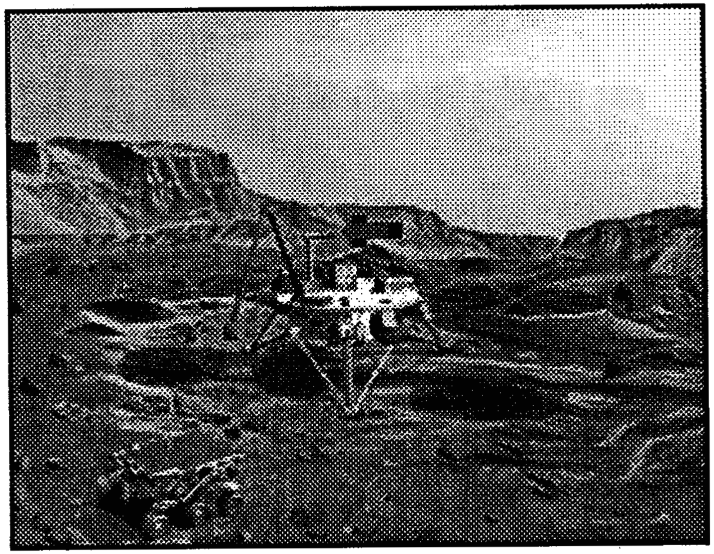
Exception is a controlled Rad Hard process line

**Radiation risk mitigation techniques are often required- $$$**

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

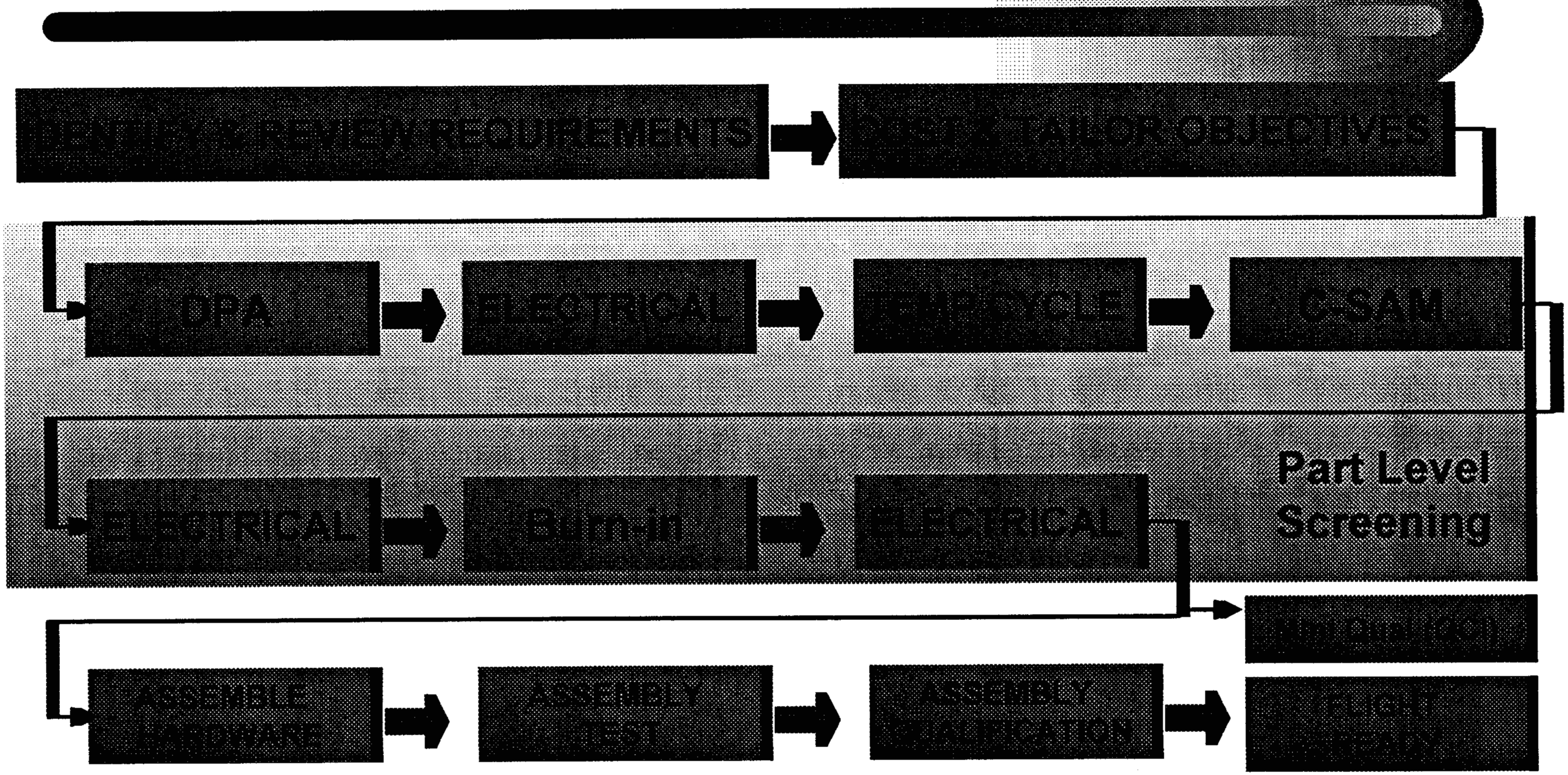
# MARS01 Pancam Plastic Parts Reliability Requirements:

- Mission Life $\leq$ 1 years (1500 hours operating)
- Operating Temperature (day only) = -50°C to +10°C
- Number of T/C $\approx$ 365
- No Assembly Board Burn-In Planned
- Outgassing is a concern
- Environmental Moisture is not critical



Lander & Rover

**JET PROPULSION LABORATORY**
**Electronic Parts Engineering Office**




**COTS$^{++}$ Plastic Infusion Baseline Flow (Tailored for MARS01 application/mission requirements)**

## DPA Results (No. of Rejects):

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| External Visual: Pass | External Visual: Pass | External Visual: Pass |
| Radiographic: Pass | Radiographic: Pass | Radiographic: Pass |
| Internal Visual: Pass | Internal Visual: Pass | Internal Visual: Pass |
| SEM: Pass (0/4) | SEM: Pass (1) (1/8) | SEM: Pass (0/4) |

(1) Voids found in the sidewall metalization at contact windows and was observed to be thin for one part. Although all parts were of the same date code, the dice were clearly from different processing lots.

Note: Reject criteria was defined by JPL to be a potential risk to mission success.

## Initial Electrical Test Results (Pre T/C & C-SAM - No. of Rejects):

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| At +25°C: 0/78 | At +25°C: Not tested | At +25°C: 0/78 |
| At -55°C: 0/78 | At -55°C: Not tested | At -55°C: 1/78(1) |

**(1)** Failed parametric

Note: T/C condition = -60C to +25C (10 cycles)

## Reported Failure Mechanisms from PEM Delamination:

- Stress-induced passivation damage over the die surface
- Wire bond degradation due to shear displacement
- Accelerated metal corrosion
- Die attach adhesion
- Intermittent electricals at high temperature
- Popcorn cracking
- Die cracking

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

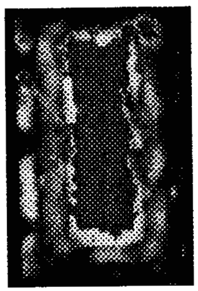
## C-SAM Results (No. of Rejects):

**Amplifier - Vendor A**

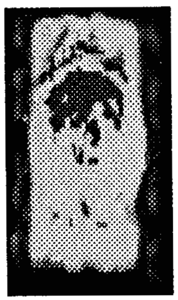
Top Side: 0/78[1]

Back Side: 3/78

**Typical Rejects:**



Pass [1]

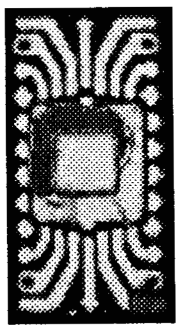


Fail

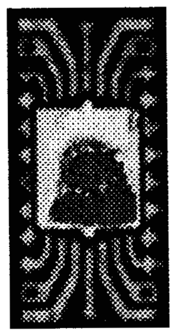
**ADC - Vendor B**

Top Side: 30/78

Back Side: 8/78



Fail

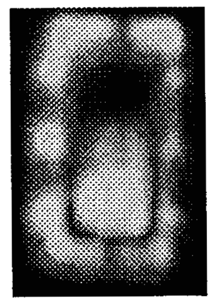


Fail

**DC-DC Converter - Vendor C**

Top Side: 0/78

Thru Scan: 16/78



Fail

Note: Units with delamination are defective and were defined by JPL to be a potential risk to mission success. (1) All units showed 100% delamination caused by a special die top coating.These parts were not rejected. F.A .confirmed a die top coating. This was validated by the supplier as a gel coat and is used to relieve stress of the die and improve performance.

# Electrical Test Results (Pre Burn-In - No. of Rejects):

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| At +25°C: 0 | At +25°C: 10 (1) | At +25°C: 2(1) |
| At +55°C: 0 | At +55°C: 0 | At +55°C: 1(1) |

**(1)** Failures included parametric and functional

# Electrical Test Results (Post Burn-In - No. of Rejects):

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| At +25°C: 0 | At +25°C: 0 | At +25°C: 0 |
| At -55°C: 0 | At -55°C: 3[(1)] | At -55°C: 0 |

**(1)** Failures were parametric and functional

Note: Burn-In Conditions = Dynamic at 72 hrs, @+55C, @max rated Vdd. This condition was calculated to simulate 1500 hrs at -10C using a T acceleration factor of 21 & Ea=.33ev. The 3 burn-in circuits simulated the actual operation of the parts.

# Electrical Test Results (QCI - No. of Rejects):

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| At +25°C: 0 | At +25°C: 0 | At +25°C: 0 |
| At -55°C: 0 | At -55°C: 0 | At -55°C: 0 |

Note: All parts passed (ss = 10 good parts/part type)

Note: Burn-In Conditions = Extended dynamic at 72 hrs, @+55C, @max rated Vdd. This condition was calculated to simulate additional 1500 hrs at -10C using a T acceleration factor of 21 & Ea=.33ev. The 3 burn-in circuits simulated the actual operation of the parts.

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

# Circuit Card Assembly (CCA) Risk Reduction:

| Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|
| Unit yield: 75/78 | Unit yield: 31/78 | Unit yield: 61/78 |

**W.C.Failure Rate Expected Before Screen (COTS):**

$= 100\%(1- [75/78^{\wedge 1} \times 31/78^{\wedge 1} \times 61/78^{\wedge 1} \times 100/100^{\wedge 1} \times \ldots\ldots.]) \text{ or } \leq 70\%$

**W.C.Failure Rate Expected After JPL Screen ( COTS$^{++}$ ):**

$= 100\%(1- [.990^{\wedge 1} \times .985^{\wedge 1} \times .950^{\wedge 1} \times 100/100^{\wedge 1} \ldots..]) \text{ or } \leq 8\%$

**Potential Risk of failure has been reduced by ≈ 62%**

Note: Vendor B product is potentially more at risk because of high number of pre and post BI rejects as well as the number of package related defects. Rejects and defects were rated as equal risk.

# VALUE ADDED ANALYSIS (Cost):

| | Amplifier - Vendor A | ADC - Vendor B | DC-DC Converter - Vendor C |
|---|---|---|---|
| **Part Acquisition Cost:** | \$.260k | \$1.8k | \$.350k |
| **Part Screening Cost:** | \$6.8k | \$13.8k | \$6.3k |
| **Engineering O/H Cost:** | \$2.0k | \$2.5k | \$2.0k |
| **Value added for screening/CCA:** | \$8.8k/9 + \$16.3k/9 +\$8.3k/9 = \$3.7k | | |

**Risk of Failure Cost Before Screen:** \$30k(all material & labor) x 9 x .70 f.r. = \$189K

**Risk of Failure Cost with Screen:** (\$30k + \$33.4k) x 9 x .08 f.r. = \$45.6k (>400% Potential Savings)

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

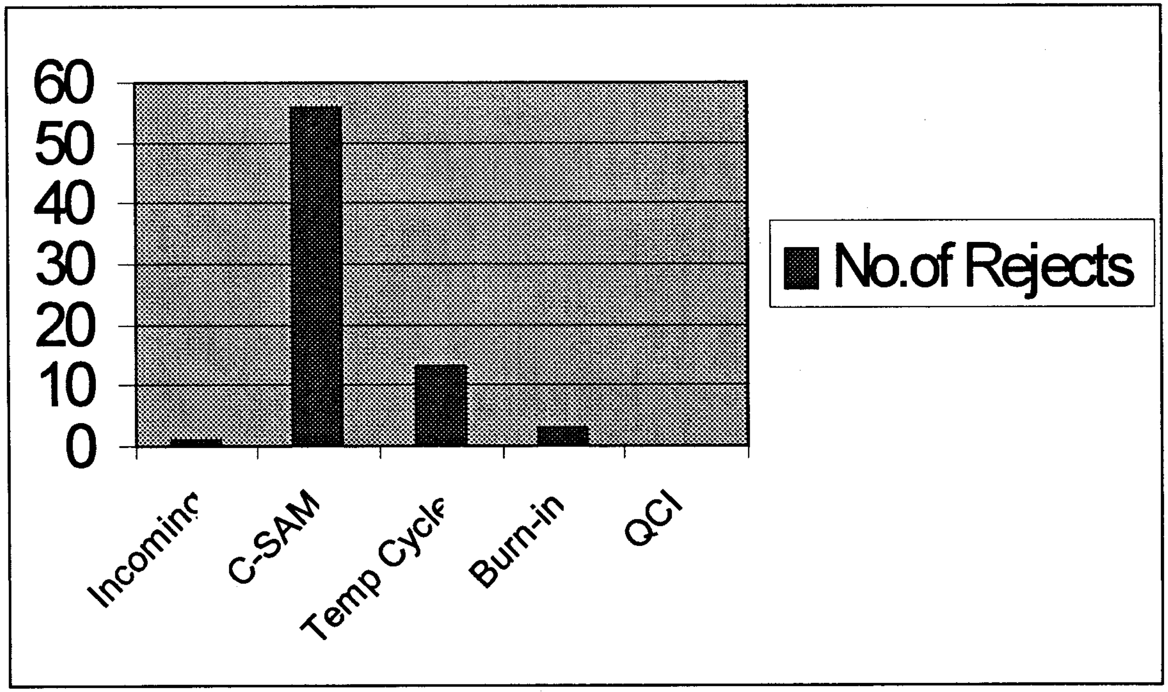
# COTS$^{++}$ PEM Upscreen Impact on Risk Mitigation:

| | Amplifier | ADC | DC-DC Converter |
|---|---|---|---|
| • Narrow Temperature Range for Commercial Grade | 1 | 1 | 3 |
| • Plastic Assembly Quality | 3 | 9 | 9 |
| • Lot Non- Uniformity & Traceability | 1 | 9 | 3 |
| • Adequacy of Vendors Testing | 1 | 9 | 3 |
| • Infant Mortality | 1 | 9 | 1 |
| • Die Construction and Quality | 1 | 1 | 1 |
| Total Score | 8 | 38 | 20 |
| COTS$^{++}$ Impact on Lowering Risk | Low | High | High |

Risk mitigation weighting factors used: Minimum = 1, Moderate = 3, Significant = 9

# Summary/Conclusions:

## COTS++ Upscreening Results




**Incoming = 0.42%**

**C-SAM = 24.35%**

**Temp Cycle = 5.55%**

**Burn-in = 1.28%**

**QCI = 0.00%**

**Total = 31.60% (3 types)**

**Total = 24.8% (5 types)**

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

# COTS$^{++}$ Upscreening Rejects by Part & Vendor

| | Amplifier-Vend. A | ADC-Vend. B | DC-DC Con.-Vend.C | Voltage C-Vend.A* | S.Regulator-Vend.B* |
|---|---|---|---|---|---|
| DPA: | 0/4 | 1/8 | 0/4 | In progress | In Progress |
| Incoming: | 0/78 | n/a | 1/78 | 0/80 | 8/80 |
| C-SAM: | 3/78 | 38/78 | 16/77 | 4/80 | 0/80 |
| Temp Cycle: | 0/78 | 10/78 | 3/77 | 0/80 | 3/72 |
| Burn-In: | 0/78 | 3/68 | 0/74 | 0/80 | 9/69 |
| QCI: | 0/10 | 0/10 | 0/10 | 0/10 | 0/10 |
| Total: | 3/78 | 51/78 | 20/78 | 4/80 | 20/80 |

* New data with different part numbers

# Summary/Conclusions:

• The concerns/risks anticipated with using COTS PEMS have been validated from the results of the tailored screening flow used.

•The tailored screening flow used has significantly reduced the potential risk of failure for the MARs01 CCA by approximately 60%.

• The cost of failure for future CCAs manufactured with the screened parts has been reduced by a much as 400% (before launch).

• Using COTS PEMs without any value added screening/characterization will jeopardize any Project until the unknown risks/concerns are understood and mitigated.